METHOD FOR THE MANUFACTURING OF A CONE CUTTER FOR ROTARY DRILLING BY CRUSHING, A ROTARY CONE DRILL BIT, A CONE CUTTER AND CRUSHING ELEMENTS THEREFOR

Background of the invention

[0001] This application is based on and claims priority under 35 U.S.C. §119 of Swedish Patent Application No. 0001598-2, filed May 3, 2000, the disclosure of which is incorporated by reference herein.

[0002] The present invention relates to a method for the manufacturing of a cone cutter for rotary drilling by crushing, a rotary cone drill bit, a cone cutter and a crushing element.

Prior Art

[0003] A rotary cone drill bit is intended to drill earth by crushing rock material. This is achieved by generating an axial feed force and rotation force via drilling machine and transferring those forces via tubes to the end where the drill bit is secured. The crushing itself is achieved by crushing elements such as buttons or chisels of cemented carbide, which are positioned in annular external rows on the cone cutter body. The buttons are submitted to high strains during drilling. Today the buttons or the chisels are secured by being pressed into drilled holes. The buttons are held by friction to the bore wall in the drilled holes. The bore wall in the cone cutter body receives the bending moment applied to a button. These parameters require relatively deep holes in the cone cutter body, that is holes in the magnitude of 5-20 mm, depending of the dimensions of the cemented carbide and therefore the geometry of the cone cutter body must be oversized. Since the volume of the cone cutter body is limited, also the number of buttons and their possible positions become limited. Thereby the options for dimensioning of the

bearings in the drill bit become limited. In addition, only a smaller part of the cemented carbide of the button is used for drilling.

Objects of the Invention

[0004] One object of the present invention is to provide a method for the manufacturing of a cone cutter for rotary drilling by crushing and a rotary cone drill bit and a crushing element, which counteract the above-captioned drawbacks.

[0005] Another object of the present invention is to provide a rotary cone drill bit and a cone cutter, which allow great opportunities regarding cavities in the cone cutter body.

[0006] Another object of the present invention is to provide a rotary cone drill bit, which allows more durable bearings in the cone cutter body.

[0007] Still another object of the present invention is to provide a crushing element, which enables a simple mounting to the cone cutter body.

[0008] Still another object of the present invention is to provide a method for the manufacturing of a cone cutter for rotary drilling by crushing, which is fast and efficient.

Summary of the Invention

[0009] One aspect of the present invention involves a rotary cutting head for cutting rock by crushing. The cutting head comprises a support, and a cone cutter rotatably mounted by bearings on the support. Rows of welded-on crushing elements are adhered to a base body of the cone cutter by a metallurgical bond. Each crushing element comprises a body having a working portion, an opposing mounting portion, and an intermediate portion from which the working and mounting portions extend. Each crushing element has a greatest width D at the intermediate portion, and a greatest

height H extending from a tip of the working portion to a transition between the intermediate portion and the mounting portion, wherein H/D < 1.2.

[0010] Other aspects of the invention relate to the cone cutter per se and the crushing elements per se.

[0011] Another aspect of the invention relates to a method of manufacturing a rotary rock-crushing cone cutter which comprises the steps of:

[0012] A) providing a base body and a plurality of crushing elements, each crushing element comprising a body having a working portion, an opposing mounting portion, and an intermediate portion from which the working and mounting portions extend, each crushing element having a greatest width D at the intermediate portion, and a greatest height H extending from a tip of the working portion to a transition between the intermediate portion and the mounting portion, wherein H/D is less than 1.2;

[0013] B) connecting the base body to one pole of an electric circuit, and connecting one of the crushing elements to another pole of the circuit;

[0014] C) bringing a surface of the mounting portion of the crushing element toward a supporting surface of the base body and energizing the circuit to create an electric arc between the mounting portion and the supporting surface;

[0015] D) maintaining the arc sufficiently to melt both the surface of the mounting portion and the supporting surface;

[0016] E) pressing the melted surfaces together;

[0017] F) permitting the pressed-together melted surfaces to solidify; and

[0018] G) repeating steps B-F for the remaining cutting elements.

Brief Description of the Drawings

[0019] The objects and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings, in which like numerals designate like elements, and in which:

[0020] Fig. 1A shows a part of a cutting head in the form of a rotary cone drill bit according to the present invention in a cross-section;

[0021] Figs. 1B and 1C show magnifications of two respective areas of Fig. 1A having crushing means according to the present invention;

[0022] Fig. 2A shows an alternative embodiment of a toothed drill bit according to the present invention in a cross-section in a perspective view;

[0023] Fig. 2B shows a magnified tooth according to the present invention of the rotary cone drill bit in Fig. 2A;

[0024] Fig. 3A shows a first stage of a process for attaching a cutting element to a supporting surface wherein the cutting element is being brought toward the cutting surface;

[0025] Fig. 3B shows the cutting element making contact with the supporting surface to close an electric circuit passing through the cutting element and the supporting surface;

[0026] Fig. 3C shows an electric arc generated between the cutting element and the supporting surface;

[0027] Fig. 3D shows the electric arc spreading;

[0028] Fig. 3E shows the electric arc melting a surface of the cutting element and the supporting surface;

[0029] Fig. 3F shows the melted surfaces being pressed together;

[0030] Fig. 3G shows a metallurgical bond formed between the pressed-together surfaces after those surfaces have hardened;

[0031] Fig. 4 shows a button according to the present invention in a side view;

[0032] Fig. 5A shows a first stage of another welding process for attaching a cutting element to a supporting surface according to the present invention wherein the cutting element is in contact with the supporting surface prior to closing an electric circuit passing through the cutting element and the supporting surface;

[0033] Fig. 5B depicts the cutting element being lifted away from the supporting surface simultaneously with the creation of an electric circuit, whereby an electric arc is formed;

[0034] Fig. 5C shows the electric arc spreading;

[0035] Fig. 5D shows the electric arc melting the surface of the cutting element and the supporting surface;

[0036] Fig. 5E shows the melted surfaces being pressed together;

[0037] Fig. 5F shows a metallurgical bond formed between the cutting element and the supporting surface after the melted surfaces have been allowed to solidify;

[0038] Fig. 6 shows a second preferred embodiment of a cutting element according to the present invention;

[0039] Fig. 7 shows a third embodiment of a cutting element according to the present invention;

[0040] Fig. 8 shows a fourth embodiment of a button according to the present invention;

[0041] Fig. 9 shows a fifth embodiment of a button according to the present invention; and

[0042] Fig. 10 shows a sixth embodiment of a button according to the present invention.

Detailed Description of Preferred Embodiments of the Invention

[0043] With reference to Fig. 1A, a rock drill bit 1 according to the present invention is shown, the bit designed for the rotary crushing drilling of rock, i.e., a so called rotary cone drill bit. The cutting head in such a device is in the form of a drill bit which comprises three supports in the form of legs 10. One leg 10 is shown in section in Fig. 1A, on which journals 11 are provided. A roller or cone cutter 12 equipped with crushing elements in the form of buttons 14, is rotatably mounted on each journal by means of roller bearings 29, a system of ball bearings 15, a radial bearing 16 and an axial bearing 17. The buttons can alternatively be replaced by other crushing elements, such as chisels or teeth 14' (Fig. 2A) integrated with the base body 12A' of the cone cutter. The legs 10 are evenly distributed about the periphery of the bit with 120° partition. The journal 11 is provided with a channel 18 for introducing the ball bearings 15, in which a plug 19 is received in order to retain the ball bearings 15. The cylindrical roller bearing 29 receives a major part of the reactional force from the rock while the major object of the ball bearings 15 is to retain the cone cutter 12 on the journal 11. The cone cutter has a shoulder 20 to abut against a collar 21 on the journal for receiving axial forces, which are not received by a support disc cooperating with the axial end surface of the journal. The bit is provided with flushing channels 34 for flush medium, such as pressurized air with an addition of water for cooling and cleaning of the bearing system. The above-mentioned internal bearings can be sealed and lubricated by a lubricant system integrated with the bit. The cone cutter has intermediate grooves between the external rows of buttons to accommodate buttons of other cone cutters in the drill bit.

[0044] Each button has a working end and the shape of the button end may vary considerably. It can thus be semi-spherical, conical, ballistic, semi-ballistic or chisel shaped.

[0045] The buttons are made from wear resistant cemented carbide, such as wolfram carbide and cobalt pressed together whereafter the formed body is sintered. Since cemented carbide is an expensive material the cost of the drill bit would sink if the cemented carbide portion that normally is pressed downwards into the hole in the steel body could be eliminated. The cost for manufacturing should also be lower if hole drilling did not have to be performed. In the present invention the cemented carbide is directly secured to the steel body 12A by welding. Welding means that the surfaces are heated and are pressed together such that a so-called metallurgical bond with high strength is obtained between the two materials.

[0046] A problem involving welding of cemented carbide results from the high carbon content thereof. The carbon content in the steel closest to the joint will increase at melting, with the risk of brittleness. To limit this risk, a short welding time is chosen, which puts special demands on the choice of welding method.

[0047] A suitable method where specifically short welding time is characteristic is the capacitor charge spot welding, which is illustrated in Figs. 3A-3G. The method involves connecting the button 14A and the body 12A of the cone cutter to a circuit in which a capacitor pack, not shown, is discharged. A specially formed integral spigot 22 on the button makes the electric current very high locally and an electric arc 43 arises. This electric arc vaporizes the spigot and melts the adjacent surfaces. The button is pressed or pushed against a smooth supporting surface 13 of the base body 12A of the cone cutter wherein the melt solidifies and a metallurgical or chemical bond arises. The course of welding is very fast, in the magnitude of 1-5 milliseconds (ms), and its stages are successively shown in Figs. 3A-3G. Welding can also be made without a gap, i.e. without step A in the figure, and then the welding time becomes somewhat longer but no longer than 1

second. The stages of the method according to the present invention with reference to Figs. 3A-3G comprise:

[0048] A) The capacitor pack is charged and the button 14A is accelerated towards the smooth surface 13 of the body 12A of the cone cutter. By the expression “smooth surface” is here meant a substantially planar surface which also can be slightly convex as in Fig. 1A or concave, i.e., the surface is not machined into a recess of the substantially reverse shape of the lower side of the crushing element.

[0049] B) The spigot 22 engages the surface 13 and will short out the capacitor pack.

[0050] C) The spigot 22 is vaporized by an electric arc 43 formed between the button and the body of the cone cutter.

[0051] D) The electric arc spreads.

[0052] E) The electric arc melts the surface layers of both the button and the body 12A.

[0053] F) The button is pressed downwards into the body of the cone cutter and welds the material together.

[0054] G) The melt layers immediately solidify in an essentially conical weld joint 41 and the welding is finished.

[0055] In Figs. 1B and 1C it is illustrated that the solidified material, mostly steel, forms an upset 40 about each button. The thickness of the weld joint lies within the interval of 1 - 300 micrometer (μm). Fig. 1C shows welded protective buttons 30 of cemented carbide, which are applied to maintain the diameter of the drill bit constant for a longer period and to protect the steel leg from wear in exposed areas.

[0056] The button 14A, which has been adapted to the method according to the present invention, is shown in Fig. 4. The button of cemented carbide has an intermediate portion in the shape of a substantially cylindrical shank

portion 23, and a semi-spherical working portion 24 extending downwardly therefrom. The button has a center axis CL. The end surface defines a radius R, the center of which lies in a plane P. The shank portion 23 has a greatest width in the form of a greatest diameter D. The spigot 22 extends symmetrically about the central axis CL from a lower side 25A of the button. The lower side 25A extends from the intermediate portion 23 and forms a mounting portion. That mounting portion is substantially conical in shape with an internal cone angle, which is from 150° to less than 180°, preferably about 174°. The spigot has a diameter D about 0.75 mm at the intermediate portion. The shank portion 23 has a height h1 from the plane P to a transition 26 between the intermediate portion and the lower side 25A, the height h1 being from 0.2 to 2.8 mm. The spigot 22 and the lower side 25A have a height h2 of about 1.2 mm measured from the transition 26. The height H of the button constitutes the part of the button which is intended to protrude from the supporting surface, and the height H is defined as extending from the transition 26 to the peak or tip of the working portion. Suitable values regarding button dimensions for buttons according to the present invention with the most common button diameters for rotary cone drill bits has been listed in the table below. When applicable, the dimensional units are millimetres.

Diameter (D)	Protrusion (H)	Ratio (H/D)
7	3.3	0.47
7	4.9	0.7
10	3.5	0.35
10	7	0.7
12	3.7	0.31
12	8	0.67
14	4.3	0.31
14	11	0.79
16	5.1	0.32
16	14	0.88
19	8	0.42
19	15.5	0.82
21	8	0.38
21	19	0.9
max	19	0.9
min	3.3	0.3

[0057] The H/D ratio is from about 0.3 to 0.9 as is evident from the table, but is definitively smaller than 1.2, i.e. $H/D<1.2$, preferably $H/D\leq 0.9$. If the entire length H + h2 of the button is compared to the length of a conventional button it will show that the length of the button according to the present invention is about 30% - 50% of the length of the conventional button.

[0058] Welding may alternatively be made through resistance welding, which is illustrated in Figs. 5A-5G. This may be of conventional type, where heat is generated by means of electrical current, which is led through two surfaces under pressure. Especially suitable are two procedures, which resemble capacitor charge spot welding, namely the so-called SC (Short Cycle) and ARC methods. The difference compared to capacitor charge spot welding is that a transformer current source is used and the button has a wholly conical lower side instead of a spigot. The button is in contact with the body of the cone cutter from the start but is lifted up a short distance simultaneously as the current is turned on. Thereby an electric arc is formed

which melts the surfaces in the manner described above. Finally the button is pushed downwards into the body of the cone cutter and the weld is formed. The welding time, which is somewhat longer than for capacitor charge spot welding, is controlled through regulation of the time between the ignition of the electric arc and the instant when the button is pushed downwards. The SC method is illustrated in Figs. 5A-5F and comprises:

[0059] A) The button is initially in contact with the body of the cone cutter.

[0060] B) Simultaneously as the current is turned on, the button is lifted from the body of the cone cutter whereby an electric arc 43 is formed.

[0061] C) The electric arc 43 spreads between the button and the body of the cone cutter.

[0062] D) The electric arc melts the surface layer of both materials.

[0063] E) The button is pressed downwards into the body of the cone cutter and welds the materials.

[0064] F) The melt layers immediately solidify and the weld joint 41 is finished. The welding time for the SC method seldom exceeds 20 ms.

[0065] The button 14B that has been adapted to the alternative welding method according to the present invention (Figs. 5A-5F) is shown in Fig. 6. The difference between the button 14B and the above-described button 14A is that the button 14B does not have a spigot and therefore the lower side 25B consists of a wholly conical surface with an inner cone angle about 166°. An important common feature for both buttons 14A, 14B is that they have a lower side 50 whose smallest diameter is smaller than the diameter D of the button, i.e. a substantially conical weld joint 41 is obtained, which compensates for the fact that more melting of the steel normally arises at the mid section of the button. This button includes working, intermediate, and mounting portions 24B, 23B, and 25B.

[0066] The ARC method is used for greater dimensions and functions in the same manner as the SC method. Since longer welding times are used, the weld in this case is protected by means of a ceramic ring or gas. The welding time depends on the diameter, for example 200-400 ms for a button with a diameter of 10 mm, but seldom or never exceeds 1 second.

[0067] The cemented carbide can be covered with a layer of nickel or cobalt before welding such to increase strength of the joint.

[0068] Example 1: Cemented carbide buttons with a diameter of 7 mm were welded by means of capacitor charge spot welding to a steel body in a tempered steel of the TYPE SAE 4142 (SS2244). The cemented carbide buttons were shaped according to Fig. 4. At the initiation of electrical welding current, the buttons were raised by a lifting height of 1 mm. The voltage was 160 V, and pressure was 50 N and the welding time was 3 ms. Through subsequent metallographical investigation, it was authenticated that a metallurgical bond was obtained between the steel body and the cemented carbide buttons.

[0069] Example 2: Cemented carbide buttons with a diameter of 7 mm were welded by means of the SC method to a steel body in a tempered steel of the TYPE SAE 4142 (SS2244). The cemented carbide buttons were shaped according to Fig. 6. At the initiation of welding current a lifting height of 1 mm was used, the amperage was 550 V and the welding time was 20 ms. Through metallographical investigation it was authenticated that a metallurgical bond was obtained between the steel body and the cemented carbide.

[0070] An additional advantage with the methods according to the present invention is that buttons can be positioned closer to each other on the rotary cone drill bit since no button holes need to be pre-formed, and of course there is no risk for cracks to occur between pre-drilled holes since there are none.

The short welding time enables welding also of diamond coated buttons. Each button 14A, 14B according to the present invention, which is to be welded, is shorter than a corresponding conventional button, and therefor expensive cemented carbide is saved. In addition, there is no need for preparation of the weld joint on the body 12A of the cone cutter 12. The button 14A, 14B is not intended to be rotated during welding (i.e., no friction welding is used) and can therefore alternatively be asymmetrically shaped and thus needs no driving surfaces. In the asymmetric case in the formula in the claims "D" depicts the greatest width of the asymmetrical button. The height h1 of the shank of the button may be 0 to 15 mm, i.e. its working surface 24 may connect for example directly to the lower side 25A, 25B.

[0071] Fig. 7 shows a button 14C according to the present invention, with a ballistic basic form, which is somewhat more aggressive than the previously described buttons. Fig. 8 shows a button 14D according to the present invention, with a conical basic form, which is still more aggressive than the previously described buttons. Fig. 9 shows a button 14E according to the present invention such as mentioned above, with an asymmetrical, essentially conical basic form. Such as evident from Fig. 10 the button 14F according to the present invention is formed with a shoulder and an intermediate concave portion. The shoulder protects the surrounding steel in the body 12A of the cone cutter 12 from wear and gives greater welded surface. Each of the buttons of Figs. 7-10 includes working, intermediate, and mounting portions identified by numerals 24, 23 and 25 having suffixes C, D, E and F in respective ones of those figures.

[0072] Alternatively the buttons 14A-14F may be formed of material similar to the type of cemented carbide which is described in U.S. Patent No. 5,286,549 which describes cemented carbide bodies, containing WC and a binder based on at least one of Co, Fe and Ni and including a soft core of

cemented carbide surrounded by a harder surface zone of cemented carbide. It is understood that the buttons 14C-14F can be provided with a spigot 22 to enable capacitor charge spot welding.

[0073] Figs. 2A and 2B show an alternative embodiment of a rotary cone drill bit 1' according to the present invention having steel teeth. In contrast to the drill bit 1 in Fig. 1A the cone cutter 1' has no buttons, but rather has steel teeth reinforced by cemented carbide tips 14' serving as crushing elements. The tip 14' has a substantially rectangular cross-section with a greatest width D (Fig. 2B) at the weld joint. The height H of the tip constitutes the part of the tooth which is intended to protrude from the steel surface on the body 12A' of the cone cutter, and the height H is defined from the transition 26' to the peak of the tip. The H/D ratio is about 0.3 to 0.9, but is definitively smaller than 1.2, i.e. $H/D<1.2$, preferably $H/D\leq 0.9$. The lower side 25' of the tooth has a convex V-shape.

[0074] The present invention consequently provides a rotary cone drill bit for rotary crushing drilling which allows a large degree of freedom regarding the spacing between the cone cutters in the drill bit, i.e. less steel support is needed for these crushing means so deeper intermediate grooves can be made, and more available bearing space in the cone cutter. In addition, crushing element geometries are provided, and a method, which enables a simple and quick mounting of the crushing elements to the cone cutter body, which in turn, provides material technical advantages.

[0075] The present invention is also applicable to a conical cutter for a cutter head in the form of a raise boring head as described in U.S. Patent No. 5,984,024, incorporated by reference into the present description. In such a device, the conical cutters are rotatably journalled on supports in the form of yokes or saddles.

[0076] Although the present invention has been described in connection with preferred embodiments thereof, it will be appreciated by those skilled in the art that additions, modifications, deletions and substitutions not specifically described may be made without departing from the spirit and scope of the invention as defined in the appended claims.